# Assessment of Robust Control on Damage Growth

Alan Barhorst, Matt Bement

## Abstract

The past few years have seen significant advances in the fields of structural health monitoring and damage prognosis, particularly in the areas of damage detection and localization. Because of these advances, it is conceivable, for the first time, to design a structure with the ability to detect damage and take corrective action to minimize its effects and slow its progression. This project will evaluate the potential for this damage mitigating control to allow mechanical, aerospace, and civil systems to monitor their structural health, diagnose any damage, and then take action to intelligently mitigate the effect and progression of the damage. Specifically, a cantilever beam will be studied, with damage being induced/simulated in both linear and nonlinear manners. A robust controller will be designed to ensure that vibration damping characteristics are maintained. The trade off between maintaining these characteristics and doing so at the expense of increasing strain at the damaged area, which is correlated with damage growth, will then be investigated.

## Project Description and Approach

The ability of a structure to detect damage and compensate in such a way as to slow its progression has enormous ramifications from both an economic and life-safety perspective. The tragic break-up of the space shuttle Columbia during re-entry has been partially attributed to damaged tiles. This damage caused increased drag on the left wing. As a result, the flight control system had to work significantly harder to maintain optimal attitude. The initial damage to the tiles may have been so severe that nothing could have prevented the tragedy. However, it is conceivable that the control system's efforts to counter the effects of the damage (increased drag) may have inadvertently sped its progression.

A control design approach seeking to strike a balance between the objectives of maintaining system performance and preventing or slowing additional damage represents a new contribution in the field of control system design. Motivation that such a strategy is feasible comes from our own bodies. For example, if a leg is injured, we automatically strike this balance by limping. Currently, many control design techniques are available to satisfy the first objective (e.g., robust control, reconfigurable control), while little or no work has been done to satisfy the second objective, let alone a balance of the two.

This project will use a cantilever beam, similar to the one shown in Figure 1 as a testbed to assess the impact that robust control has on a damaged area of the beam. The damage to the beam will be introduced in two ways. First, damage will be simulated by applying a point mass at various places along the beam. This additional mass is meant to simulate a stiffness loss (e.g., due to a crack) at these various locations. Assuming success with the first damage scenario, a second, nonlinear scenario will be investigated. Specifically, a bolted joint will be introduced at various locations, with damage being introduced by loosening of the bolts.
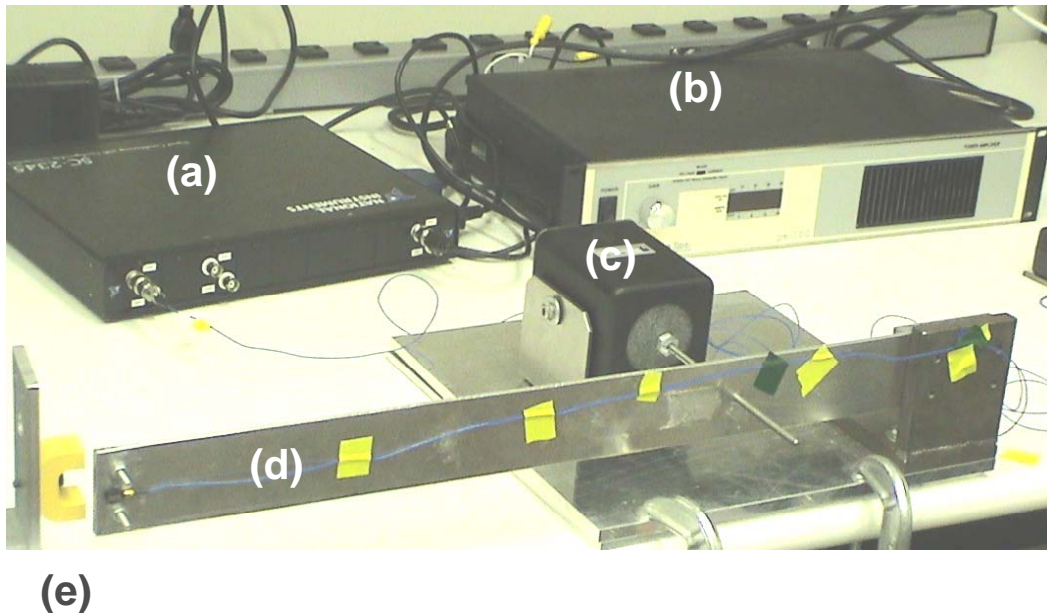
a. National Instruments signal conditioner SC2345
b. Labworks PA-138 amplifier
c. Labworks ET-132-2 electromechanical shaker
d. Test Structure – 6061 Aluminum beam with steel plate at free end
e. Permanent, stationary U-magnet (NOT APPLICABLE FOR THIS PROJECT)

Figure 1.  Experimental setup

With both damage scenarios, a robust controller will be designed to ensure certain vibration damping characteristics. Piezoelectric patches being used as actuators and strain sensors.  Accelerometers will be used to provide additional system data for feedback. Ambient vibration which is to be damped out will be introduced with a small electro-dynamic shaker.  The controller will be developed in Matlab and Simulink, and implemented via Matlab's XPC target.  Once the controller is implemented, assessments will be made regarding the strain levels at the location of damage.  The controller will then be modified to gain an understanding of the trade off between vibration damping and strain at the damaged area.

## Timeline

- Week 1:  LANL training and orientation, introduction to vibration and control.
- Week 2:  Hardware and XPC target orientation. Demonstrate control on nominal beam.
- Week 3:  Point mass damage scenario control design.
- Week 4:  Point mass damage scenario damage growth assessment.
- Week 5:  Loose joint damage scenario control design.
- Week 6:  Loose joint damage scenario damage growth assessment.
- Week 7:  Repeat necessary tests, begin write-up.
- Week 8:  Prepare presentation, complete write-up.

# References

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